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The Role of the Mobile Servicing System on Space Station

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THE ROLE OF THE MOBILE SERVICING SYSTEM ON SPACE STATION

by

Harvey L. Werstiuk and Dev M. Gossain

1.0 INTRODUCTION

Canada views the space station as one of the most significant international civilian space projects of the latter part of this century, and has made a commitment to be part of this great venture. Canada's participation in space station is two-fold:

1) a significant contribution to the development and operation of the core station by provision of the Mobile Servicing System (MSS) and;

2) a user development program which will foster participation in science and technology experiments that will be performed on the space station.

Development of the MSS will stimulate the development of strategic technologies such as automation, robotics, and artificial intelligence which are important to the growth of ground-based industries. The user development program will assist Canadian industry to participate in the development and economic benefits arising from new and improved materials and products manufactured in space.

Canada's role in the Space Station is an outgrowth of its successful participation in the National Space Transportation System (NSTS) with the supply of the Shuttle Remote Manipulator System. There is currently strong support for Canadian participation in the Space Station Program.

This paper will discuss one of these areas of participation; the role of the Mobile Servicing System (MSS) on the Space Station. The functional requirements for the MSS will be presented as well as the conceptual description of the MSS which will meet the requirements.

2.0 MOBILE SERVICING SYSTEM (MSS) FUNCTIONS

The concept of the Mobile Servicing System (MSS) has been developed to enable performance of assembly, maintenance and servicing functions in the unpressurized environment of the Station. Major functions supported by the MSS are:

a) Station assembly:
   - truss assembly
   - assembly of modules
   - attachment of station system assemblies
   - assembly of photo-voltaic and solar dynamic power systems

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b) Station operations:
- berthing and deployment of the Orbiter, Orbital Manoeuvering Vehicle (OMV) and Orbital Transfer Vehicle (OTV)
- loading and unloading the cargo bay of the Orbiter
- exchanging Logistics Modules on the Station

c) Attached payload servicing:
- assembly
- exchange Orbit Replaceable Units (ORU's)
- make/break connections and interfaces
- inspection

d) Maintenance of the Station, including maintenance of MSS:
- exchange ORU's
- make/break connections and interfaces
- inspection

The MSS, being a mobile system, will service attached payloads at their operating locations; perform Station maintenance functions at different locations as necessary; berth and deploy vehicles operating in the vicinity (from suitable locations on the Station); load and unload the Orbiter including exchange of the Logistics Modules; and transport payloads and cargo externally around the Station. The MSS will also be used in the assembly of the Station during build-up to its Initial Operations Capability (IOC). MSS capabilities are phased-in during Station assembly to meet the needs of assembly, Station operations and maintenance, and servicing of attached payloads.

The functions of MSS are complementary to those of the Servicing Facility on the Station, to be developed by the U.S. The Servicing Facility is an enclosed facility fixed at one location on the Station with the capability for environmental control. It is to be used for servicing free-flyers brought to the Station by the OMV, servicing those attached payloads which cannot be serviced at their attached locations (due to the requirements of environmental control or specialized tasks), refuelling, storing ORU's and servicing equipment, and integrating OMV's with their payloads.

3.0 ROBOTICS REQUIREMENTS FOR MSS

In order to perform the assembly, maintenance and servicing functions, the MSS should have the capability to perform tasks involving controlled manipulation of objects, and controlled mechanical interaction between objects. Typical tasks to be performed are:

a) capture/release and berthing/deployment of large objects up to the size of an orbiter;

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b) ORU exchange;

c) utility connect/disconnect;

d) connector mate/demate;

e) interface attach/detach;

f) surface cleaning;

g) thermal covers and blankets removal/installation;

h) inspection; and

i) work area and Extra-Vehicular Activity (EVA) monitoring.

The MSS should be capable of performing its functions within the constraints and objectives of the Space Station Program which require that the use of EVA be minimized and that crew productivity as well as crew automony from the ground be progressively increased. This implies the following requirements for the MSS:

i) capture/release and berthing/deployment tasks should be performed by Intra-Vehicular Activity (IVA);

ii) mechanical-interactive tasks, including dextrous manipulation should be performed by IVA;

iii) a capability for MSS autonomous operation under operator supervision will be required. This capability should allow the operator to define instructions from the actuator-level to the task level in a high-level language (robot programming), to "teach" the system tasks and to execute these tasks automatically, taking corrective action if anomalies arise during execution;

iv) automatic fault detection and isolation to the ORU level will be requi-ed;

v) self-test and diagnostics capability will be required; and

vi) an ability for the system to plan tasks and resources for a mission, within the overall Station planning framework will be required.

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4.0 DESCRIPTION OF THE MOBILE SERVICING SYSTEM (MSS)

The Mobile Servicing System concept has been developed to enable performance of the functions and roles described in Sections 2.0 and 3.0. The space segment of the MSS consists of two elements on the Station: a Mobile Servicing Centre (MSC) and an MSS Maintenance Depot (MMD).

The hierarchy of MSS elements and systems is shown in Figure 4-1. The architecture and interfaces are shown in Figure 4-2. A pictorial view of MSC and MMD is shown in Figure 4-3.

The MSS elements on the Station constitute the Space Segment of the MSS. Operations on the Station are supported by facilities on the ground. The ground segment provides the equipment for User and Mission support, integration and test, simulations, and engineering analysis. The simulations capability is provided by a Manipulator Development and Simulation Facility.

4.1 Mobile Servicing Centre (MSC)

The MSC comprises a Mobile Transporter (MT) and a Mobile Remote Servicer (MRS). The MT, provided by the U.S., carries the MRS and has the capability to move along the station truss structure as well as to change planes on the truss. The systems within the MRS are described below:

a) MRS Base System (MBS)

The MBS provides a stiff lightweight structure which attaches to the transporter and provides accommodations for attaching payloads (during transportation) and accommodations for the MSC systems shown in Figure 4-1. Thermal control provisions are provided for all the units carried on the MBS. Attachment interfaces are provided to carry payload and ORU pallets on the MBS for servicing missions. The structural configuration of MBS allows it to be packaged into the orbiter bay for transportation to orbit.

b) Space Station Remote Manipulator System (SSRMS)

The SSRMS is a large manipulator system, about 55 ft. (17 metres) long, with seven modular rotary joints. The manipulator configuration is symmetrical about the middle, and has an end-effector at each end. The manipulator is relocatable and the symmetry enables either end to act as the "base" of the manipulator. The end-effectors have additional interface mechanisms to transfer power, data and video. Force-moment sensors are incorporated at each end of the manipulator to provide force data which is used to provide feedback to the human operator as

well as to the manipulator control system for closed-loop control of the tip forces. Cameras are provided on the manipulator to provide viewing capability to the operator, and to provide inputs to a vision system. The vision system uses camera inputs to recognize targets and objects, and to provide range and attitude data for tracking by the manipulator, automatically or by operator control.

The second SSRMS may be used to position an astronaut close to a work area to perform some tasks in support of those being performed by the SSRMS. Assembly of the Solar Dynamic system and assembly of Station modules and trusses are examples of such tasks.

The SSRMS is used to handle large objects in assembly, maintenance, servicing, and operation functions of the MSS, including berthing and deployment of vehicles operating in the vicinity of the Station. It also performs servicing tasks requiring mechanical interaction using a set of tools which can be picked up by its end-effector. The physical size of the SSRMS manipulator arm, its force application capability, flexibility, and control characteristics would make it unsuitable for performing some of the handling and interactive tasks which require dexterity and precision.

The control architecture for the manipulator has a system level control computer and subsystem level processors for the joints, end-effectors, force-moment sensors, vision system and tools. The number of functional paths/strings in the architecture are governed by the fault tolerance requirements for the system. The electronics of the manipulator system are modularized and packaged into Orbit Replaceable Units (ORU's) as are the mechanical assemblies for maintenance in the unpressurized environment on orbit.

c) Special Purpose Dextrous Manipulator (SPDM)

The SPDM of the MSS provides the capability to perform dextrous tasks in assembly, maintenance and servicing such as exchanging small ORU's, connecting/disconnecting utilities, mating/demating connectors, cleaning surfaces, removing/installing thermal blankets, etc.

The SPDM consists of two small dextrous manipulators, each 4 to 6 ft. (1 to 2 metres) long, with vision systems, force-moment sensors, joints, electronics and a tool change-out mechanism at the tip of each manipulator arm. The dextrous manipulators are attached to the central body which provides accommodations for avionics, tools and other SPDM hardware. A vision system on the body provides overall views of the work area of the manipulators. The vision system in the body and the manipulators are functionally integrated to provide the capability to perform tasks with increasing autonomy. A set of tools is provided in the body. These tools can be used by either manipulator. The body also provides accommodations to carry a replacement ORU and to exchange it using the SPDM manipulators.

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d) EVA Work Station (EVA-WS)

An EVA astronaut can perform limited control of the MSC from the EVA Work Station which provides a display and control panel attached to a Manned Foot Restraint (MFR). The EVA-WS can be either attached to the MRS structure or be carried by the SSRMS.

e) IVA Control Station (IVA-CS)

The MSC and the MMD can be operated from an IVA control station which is envisaged as the Station-provided Multi-Purpose Access Console (MPAC), fixed or portable, enhanced by the addition of an MSC specific display and control system including hand controllers to operate the SSRMS and the SPDM. Station configuration will enable the IVA-CS to be located such that the operator can get direct views when necessary in performing tasks with the MSC. Operations of other servicing and maintenance systems on the Station can be co-ordinated with those of the MSC.

f) Power Management and Distribution System (PMDS)

The PMDS converts and conditions the power available from the Station (20 KHz, 208/440 VAC, single phase) and distributes it to systems on the MSC and the MMD. It manages the power utilization including controlled off-loading in support of Station power management, and provides a fault-tolerant architecture. An energy storage system (batteries) is provided on the MSC for operation during transportation between utility ports on the Station. The PMDS architecture block diagram is shown in Figure 4-4.

g) Data Management System

In order to operate the MSC, SSRMS, SPDM and MMD, a complex data management system (DMS) is required. The DMS is a distributed system providing the hardware and software necessary to support the data acquisition, storage, processing and communications needs of the systems. A facility computer and an MSC control computer are provided by the DMS. The DMS provides the real-time local data busses, interfaced to the Station core network busses, for MSS data communications among the IVA-CS, MSC, MMD, and EVA-WS, as well as the SSRMS and SPDM when located away from the MMD. The DMS MSC architecture block diagram is shown in Figure 4-5. The operational and planning software for MSS is presently envisaged to have the following software functions:

- fault detection and diagnosis
- on-orbit maintenance
- task planning
- resource management
- integration and test
- manipulator programming
- collision avoidance
- multiple arm control

h) Communications System (CS)

The CS consists of a video subsystem and an RF communications subsystem. The video system provides TV camera assemblies, pan and tilt units, lights, video bus interface units and video control units. The TV cameras interface with a Frequency Division Multiplex video bus on the MSC and on the MMD. The RF communications system has a signal processor to process video and telemetery & command data, a transmitter/receiver, and an antenna. The communications system interfaces with the Station Communications & Tracking (C&T) System. Video system and Communications system architecture block diagrams are shown in Figure 4-6a and Figure 4-6b respectively.

4.2 MSS Maintenance Depot (MMD)

The MMD provides a base system (MDBS) similar to the MBS to provide attachment interfaces for SSRMS, SPDM, and EVA-WS. Accommodations for maintenance fixtures for MSC, storage of MSC-ORU's, and provisions for EVA supported maintenance are also provided on the MDBS. The PMDS, DMS and CS of the MMD are a subset of the corresponding systems on the MSC, as shown in Figures 4-4 and 4-6. These systems support maintenance activities, and subsequent test and check-out, from the IVA-CS. Maintenance tasks can also be performed robotically on the MMD using the SPDM and SSRMS.

4.3 Phasing of MSS

The MSS equipment will be introduced on the Station in a phased manner to support the assembly, maintenance and servicing requirements as the Station is assembled and its capabilities built up on orbit. NASA studies in Phase B indicate that it may take about eighteen NSTS flights to build the Station to its Initial Operations Capability (IOC). The MSS equipment is planned to be manifested on the STS as follows:

Flight	Equipment	Weight (lbs)
1&2	Facility computer and IVA-CS	104
3	Phase-1 of MRS to include SSRMS, and portions of MBS, PMDS, DMS and CS	4146
4	Second SSRMS	1896
7	Phase-1 of MMD to include portions of MDBS, PMDS, DMS	4189
9	Additional pallet accommodations	400
12	SPDM	2861
15	Phase-2 of MRS to include EVA-WS and remaining systems to final configuration	2557
17	Phase-2 of MMD to include remaining equipment to final configuration	4694

5.0 SUMMARY

The functions, role, and architecture of the MSS have been described in this paper. The MSS concept has been developed as an effective implementation of a Station system to perform attached payload servicing as well as Station assembly and maintenance. The MSS incorporates robotics and automation to minimize EVA and to progressively increase crew productivity. Since the Station will be a permanent facility designed for indefinite operation through on-orbit maintenance and refurbishment, the MSS will be designed to be space maintainable and to provide technological transparency. The MSS system design will be required to provide "hooks" and "scars" to allow addition of advanced robotics and AI technologies which will become available after the system becomes operational.

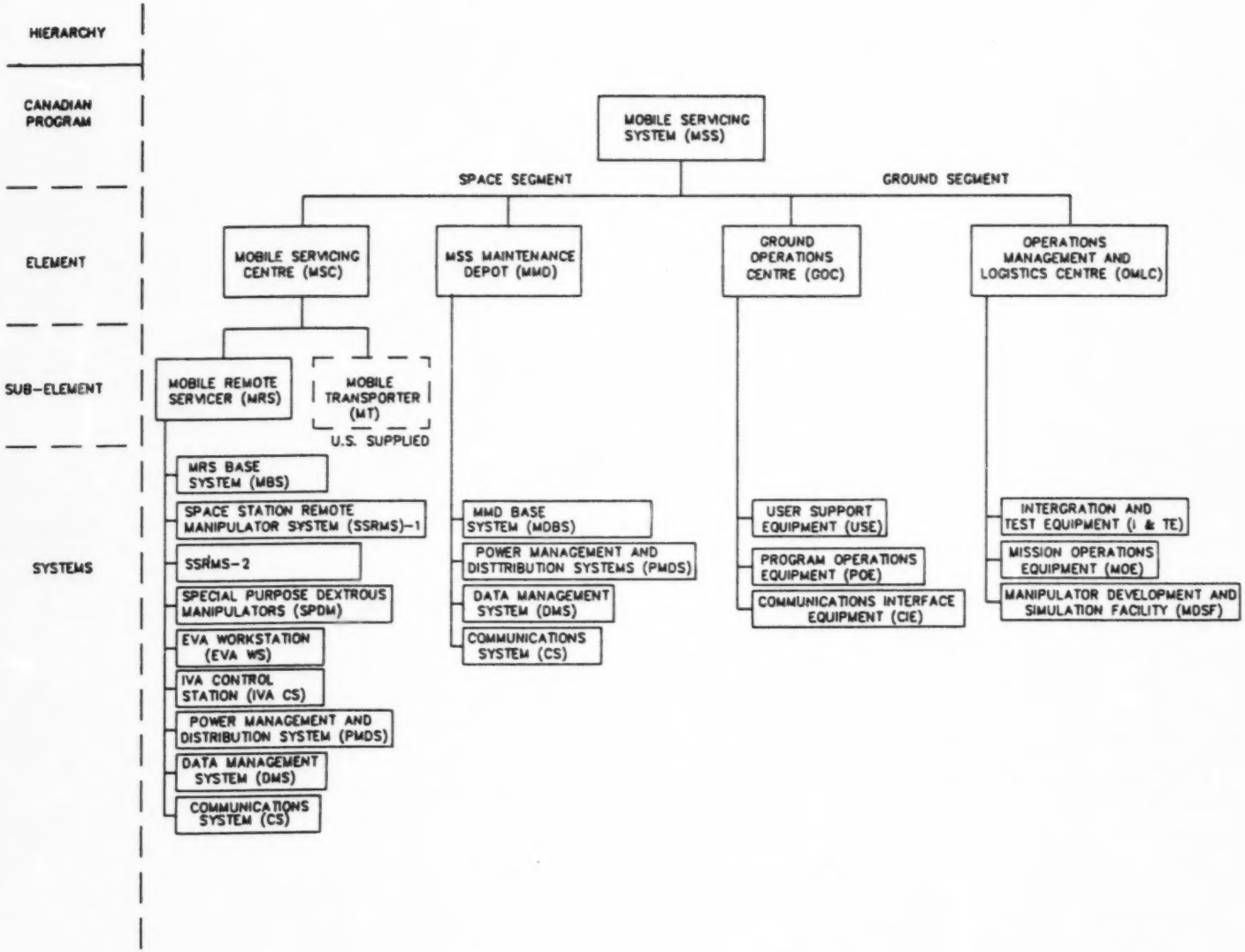

FIGURE 4-1 MOBILE SERVICING SYSTEM (MSS) HIEARARCHY

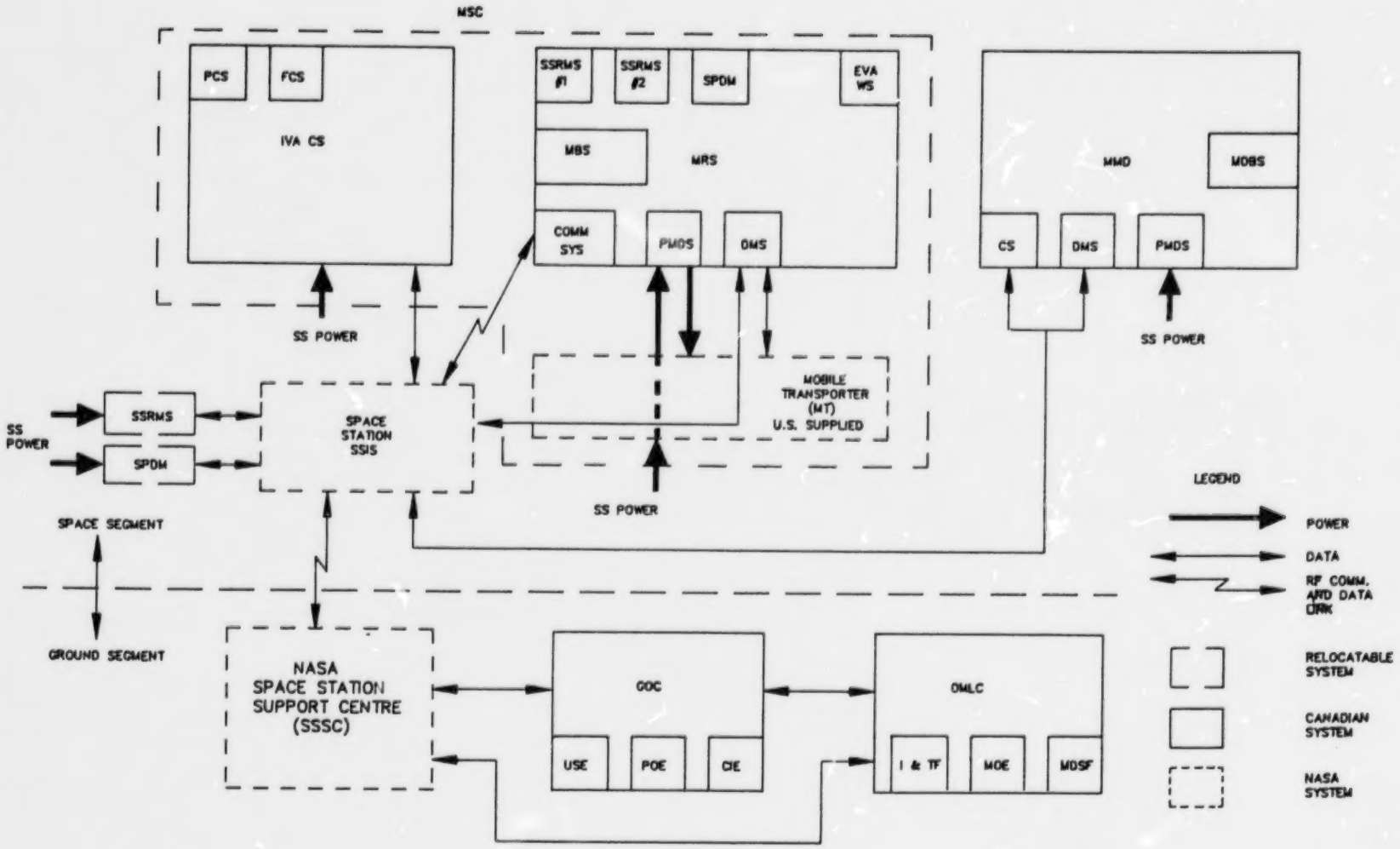

FIGURE 4-2 MSS ARCHITECTURE AND INTERFACES

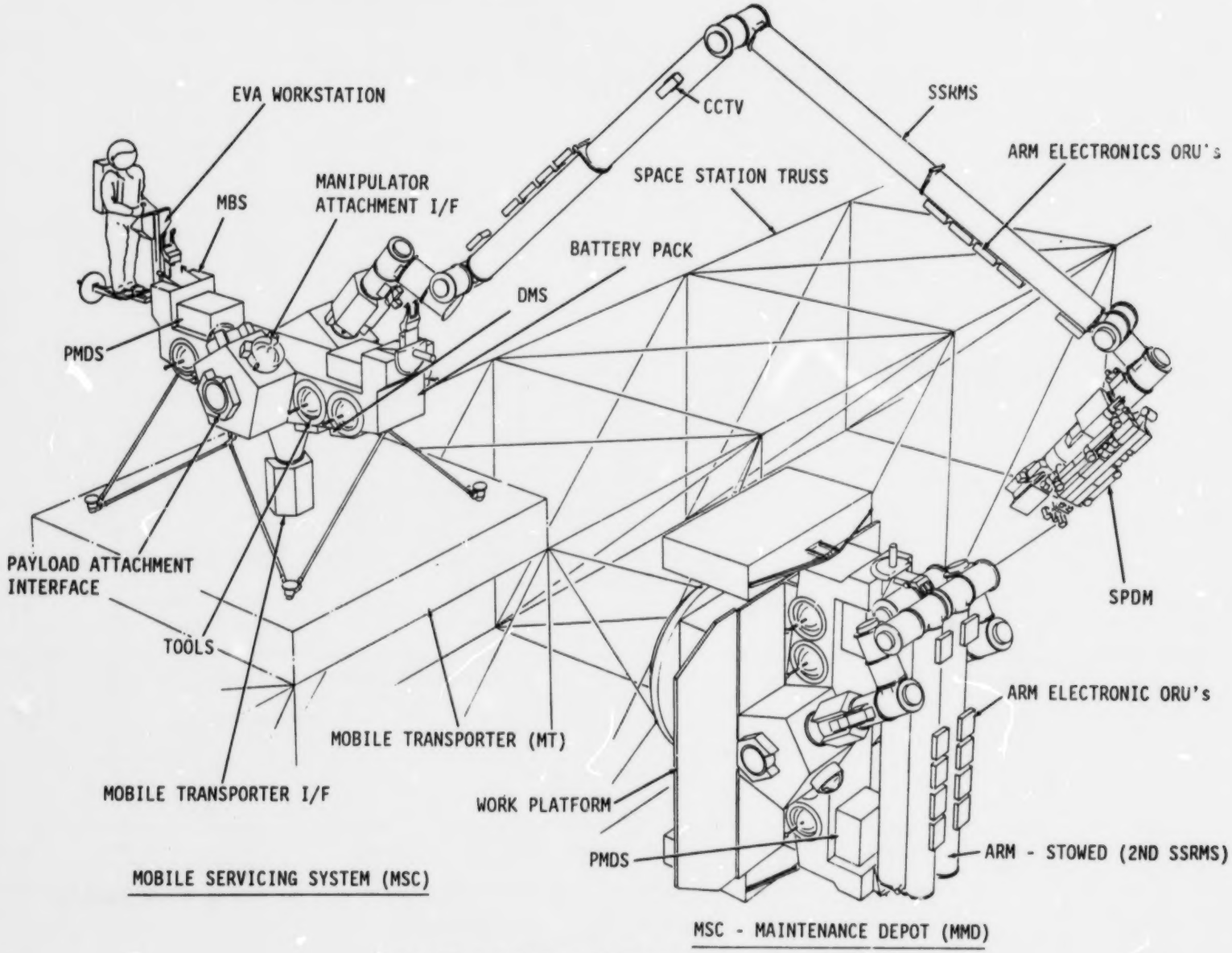

FIGURE 4-3 MSC & MMD ON THE SPACE STATION

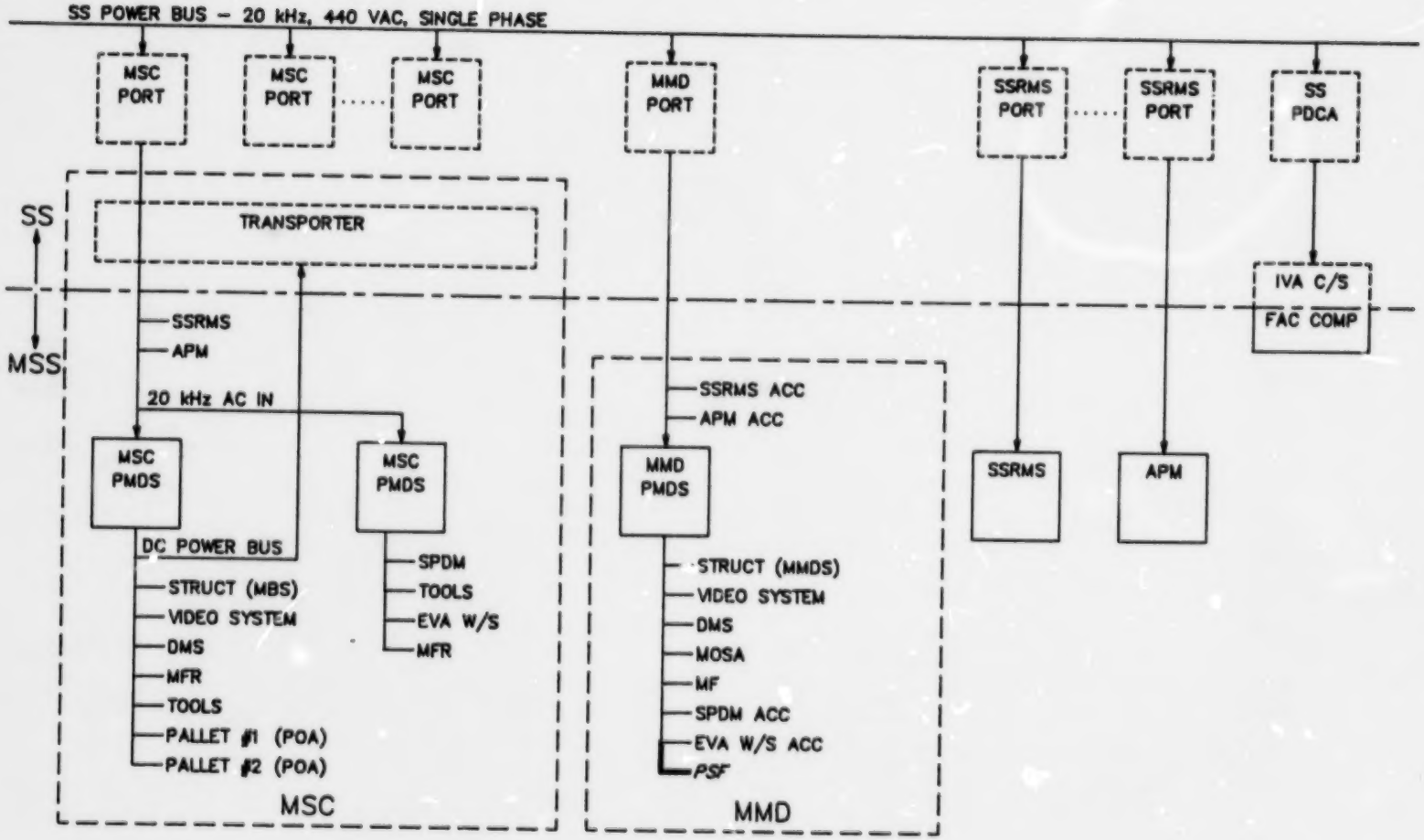

FIGURE 4-4 MSS POWER DISTRIBUTION ARCHITECTURE

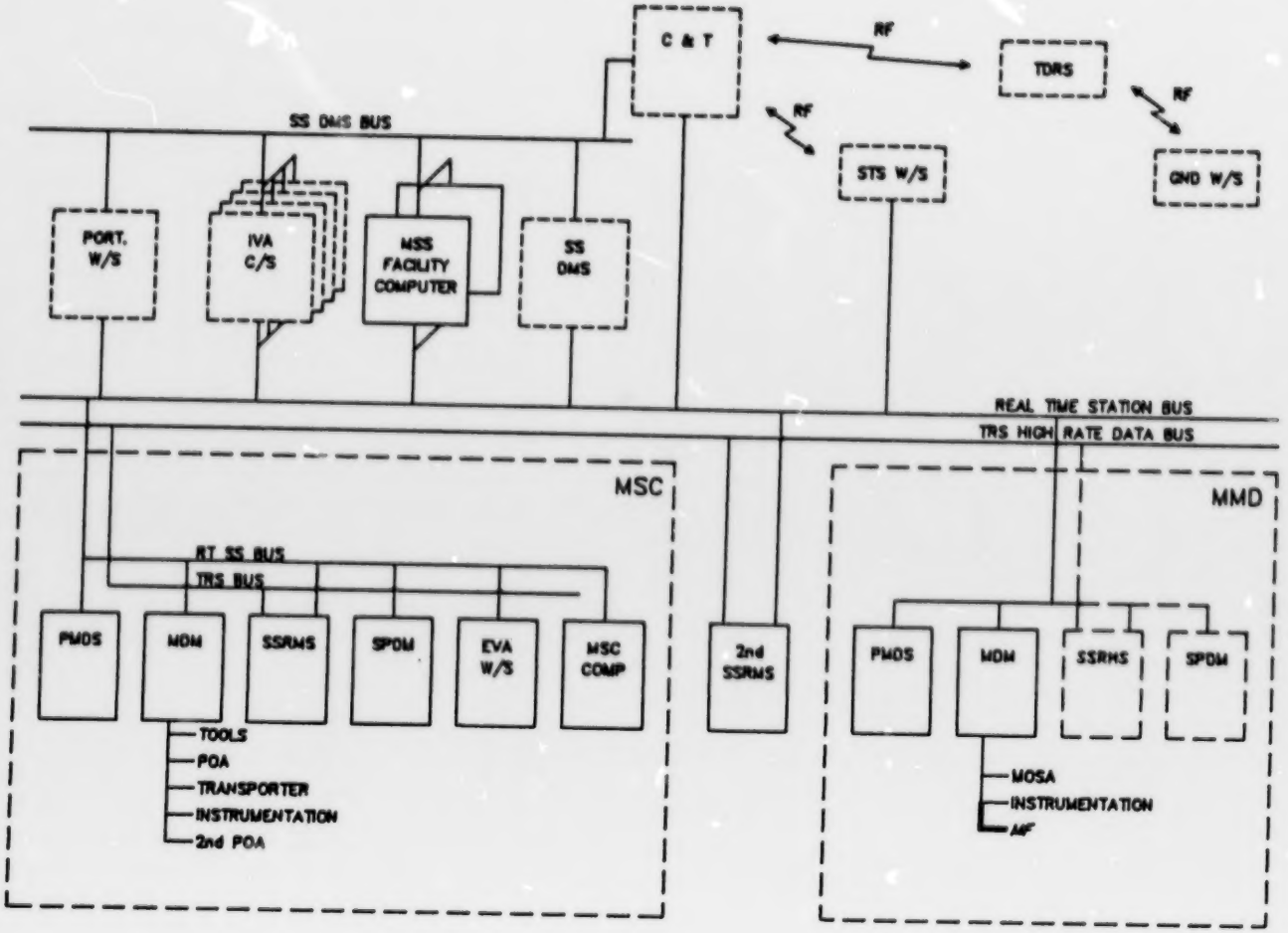

FIGURE 4-5 MSS DMS ARCHITECTURE

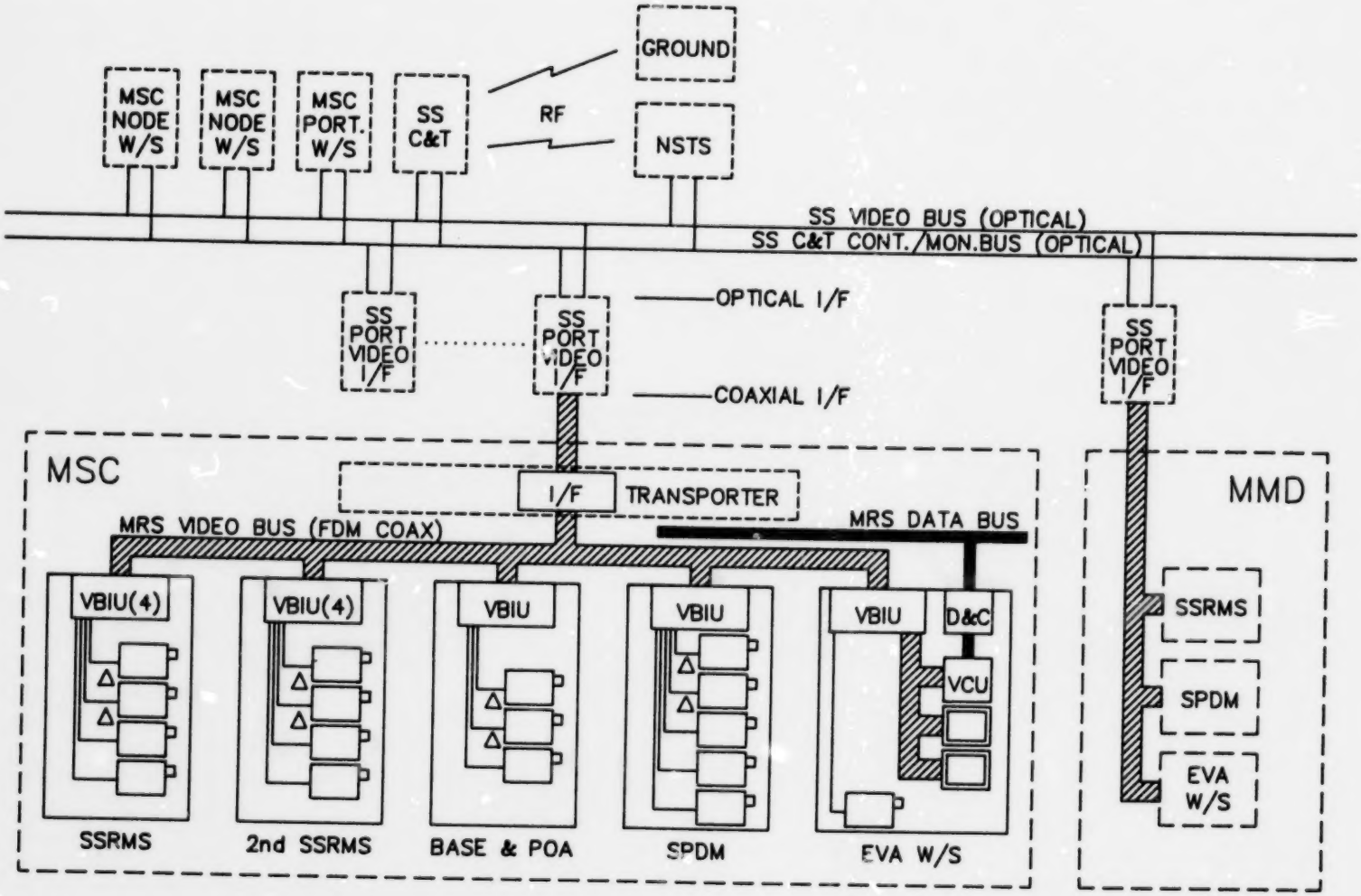

FIGURE 4-6(a) MSS VIDEO SYSTEM ARCHITECTURE

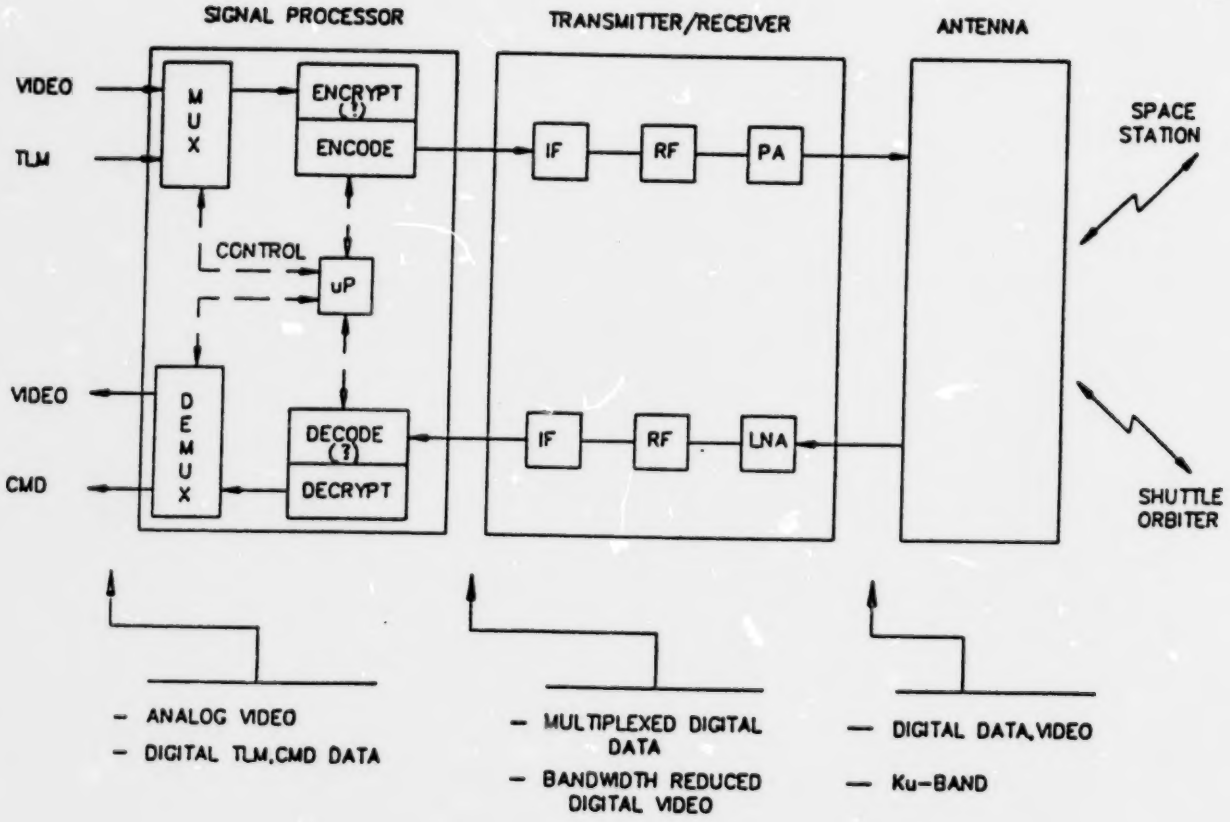

FIGURE 4-6(b) MSS RF COMMUNICATIONS SUBSYSTEM ARCHITECTURE